

WHAT IS CLAIMED IS:

1. A tantalum film having a nanocrystalline microstructure as characterized by a broad x-ray diffraction peak at $2\theta = 38^\circ$ and continuous
5 electron diffraction rings.

2. The tantalum film of Claim 1, wherein the tantalum is α -tantalum.

3. The tantalum film of Claim 1, having a resistance of $30\text{-}50\ \mu\Omega\text{ cm}$.

4. The tantalum film of Claim 1, having a net diffusion distance of less than 10 nm after annealing with copper at a temperature between $650^\circ\text{-}750^\circ\text{C}$
10 for 1 hour.

5. A tantalum film having a single crystal microstructure as characterized by an x-ray diffraction peak at $2\theta = 55^\circ$ and characteristic (100) spot diffraction pattern.

6. The tantalum film of Claim 5, wherein the tantalum is α -tantalum.

15 7. The tantalum film of Claim 5, having a resistance of $15\text{-}30\ \mu\Omega\text{ cm}$.

8. The tantalum film of Claim 5, having a net diffusion distance of less than 10 nm after annealing with copper at a temperature between $650^\circ\text{-}750^\circ\text{C}$ for 1 hour.

9. A tantalum film having an amorphous microstructure as characterized by a diffuse x-ray diffraction peak at $2\theta = 30\text{-}35^\circ$ and a diffuse ring in the electron diffraction pattern.

10. The tantalum film of Claim 9, having a resistance of $250\text{-}275\ \mu\Omega\text{ cm}$.

11. The tantalum film of Claim 9, having a net diffusion distance of less than 10 nm after annealing with copper at a temperature between $650^\circ\text{-}750^\circ\text{C}$
25 for 1 hour.

12. A method of forming a tantalum film comprising:
providing a substrate;
30 optionally, preheating the substrate;
providing a vacuum chamber;

adjusting the deposition parameters, chamber and substrate parameters as necessary to achieve the desired microstructure; and

depositing the tantalum film on the substrate in the vacuum chamber at an operating pressure of $10^{-4} - 10^{-10}$ by a method selected from the group consisting of chemical vapor deposition, thermal evaporation, (accelerated) molecular beam epitaxy, atomic-layer deposition, cathodic arc, laser assisted, metal organic, plasma enhanced, sputtering, ion beam deposition and pulsed laser deposition.

13. The method of Claim 12, wherein the operating pressure is between $10^{-5} - 10^{-10}$ Torr.

14. The method of Claim 12, wherein the method is pulsed laser deposition or molecular beam epitaxy and the laser is adjusted to an energy density of 2-5 joules/cm².

15. The method of Claim 14, wherein said deposition parameter is pulse duration and is adjusted to 10-60 nanoseconds.

16. The method of Claim 14, wherein said deposition parameter is wavelength and is adjusted to 193 to 308 nm.

17. The method of Claim 12, wherein the substrate is preheated to a temperature of between 100° to 200°C and tantalum film has a nanocrystalline microstructure.

18. The method of Claim 17, wherein the operating pressure of the vacuum chamber is $10^{-7} - 10^{-10}$ Torr.

19. The method of Claim 12, wherein the substrate is epitaxially grown and is preheated to a temperature of 600° to 750°C and the tantalum film has a single crystal microstructure.

20. The method of Claim 19, wherein the operating pressure of the vacuum chamber is $10^{-7} - 10^{-10}$ Torr.

21. The method of Claim 12, wherein the substrate is 20°-30°C during deposition and the tantalum film has an amorphous microstructure.

22. The method of Claim 21, wherein the operating pressure is $10^{-5} - 10^{-7}$ Torr.

23. A microelectronic device having a silicon substrate, a tantalum film deposited on the silicon substrate and a copper layer disposed on the tantalum film, wherein the tantalum film has an amorphous microstructure.

5 24. A microelectronic device having a silicon substrate, a tantalum film deposited on the silicon substrate and a copper layer disposed on the tantalum film, wherein the tantalum film has a nanocrystalline microstructure.

25. A microelectronic device having a silicon substrate, a tantalum film deposited on the silicon substrate, and a copper layer disposed on the tantalum film, wherein the tantalum film has a single crystal microstructure.

10 26. The device of Claim 25, wherein the device has a buffer layer of TiN or TaN deposited between the silicon substrate and said tantalum film.

27. A method of depositing a tantalum film on a substrate comprising energizing the tantalum; depositing the tantalum on a substrate; and quenching the tantalum to kinetically trap the amorphous form at a temperature that formation of
15 crystalline phase is suppressed.

28. The method of Claim 26, wherein said temperature is 20°-600°C.